



Materials and
Chemistry
Laboratory, Inc.

Use of Apatite for Chemical Stabilization of Subsurface Contaminants

Technology Need:

Metal contaminants occur in soil and groundwater at several major DOE sites. Metals of concern include uranium, chromium, lead, mercury, cadmium, arsenic, and barium. Cost effective means are required to minimize the migration of these toxic metals into groundwater systems that can spread the contamination. The baseline method for treatment of contaminated soil typically employs *ex situ* technology, which is both expensive and fraught with safety challenges during excavation and handling. Competing *in situ* technologies have proven so far to be extremely difficult on a large-scale, incapable of treating some metals (such as cesium, strontium) and are very high in cost.

Technology Description:

The Materials and Chemistry Laboratory, Inc. (MCL) has evaluated an *in situ* phosphate induced metal stabilization (PIMS) process that uses Apatite II™, developed by Dr. Judith Wright of PIMS NW, Inc. (U.S. patent no. 6,217,775), to stabilize aqueous metals and radionuclides. Apatite II™ is a commercially available form of apatite, which is a family of substituted calcium phosphate phases that serves as the source of phosphate in this PIMS process. Apatite II™, supplied by PIMS NW, Inc., is a biogenic form of apatite, derived from fish bones, and is relatively inexpensive.

The PIMS technology using Apatite II™ will be deployed either in a permeable reactive barrier or with soil mixing to effect a stabilization of the contaminants of concern. PIMS utilizes chemical precipitation to modify the chemical form of the metal in order to decrease its solubility in water and render the modified metal compound immobile in the soil phase. This in turn may reduce the bioavailability and thus the potential toxicity of the metal.

Some of the more frequently encountered metals of concern, such as uranium, lead and cadmium, are known to form highly insoluble phosphate salts (mineral phases, some of which occur naturally as geologically stable metal ores). Several other metals may also be amenable to PIMS. An economical means to provide a continuous low level of reactive phosphate *in situ* is the use of Apatite II™, applied at low dosage as a soil amendment.

Properties that make the Apatite II™ product superior to other phosphate minerals or their precursors for use in *in situ* chemical stabilization of metal contaminants include 1) a high degree of carbonate ion substitution, 2) a low degree of fluoride ion substitution, 3) no heavy metals initially present in the material, 4) a poorly crystalline structure (which enhances the solubility of the apatite phase, and thus the rate of phosphate ion release), and 5) a high degree of internal porosity. These physical and chemical properties make Apatite II™ especially reactive with metal contaminants. The performance of Apatite II™ has been compared to other more costly media (including zeolite, activated carbon, metal oxides and other mineral phases, organic-based ion exchange media, zero-valent iron, etc.) for the removal of select-priority toxic metals from solution phase. The apatite medium was found to be significantly more effective for treatment of the metals lead, cadmium, zinc, and uranium, especially in the presence of co-contaminants such as nitrate ion that interfered with sorption and ion-exchange treatment mechanisms.

Benefits:

- Eliminates excavation: apatite amendment may be used to intercept contaminants in a groundwater plume or soil vadose zone, or to isolate a contaminant source without the need for excavation.



►Permits substantial cost savings: the potential cost savings of *in situ* stabilization of metals is tremendous, compared to excavation and leaching or landfill of soil or water, or pump-and-treat technologies for groundwater. Cost savings also will be significant compared to alternate *in situ* treatment technologies.

►Allows for comparatively fast implementation times.

Status and Accomplishments:

This project was initiated in September 2001 and is in the second phase of a two-phased effort. During this project, the PIMS approach, using Apatite IITM, is being evaluated at the MCL's facility in Oak Ridge, TN. The study will evaluate the leaching of metals from contaminated soils, with and without apatite amendment using batch tests and column studies. This research will utilize soil contaminated with uranium and metals from an industrial site. The TCLP protocol will be used to initially assess this leachability potential. In addition, leachability tests will be performed using de-ionized water, according to the protocol of Beckwith (1964).

Soil column studies will be used to access the leachability of uranium and selected metals from the apatite-amended soil by percolating uncontaminated synthetic groundwater through the columns. This will be compared to the leach rate of these contaminants from the untreated soil. The release rate of soluble phosphate from apatite-amended soil will also be monitored.

Soil columns will also be used for contaminant breakthrough studies to evaluate the use of PIMS as an permeable reactive barrier. The metal of interest will be supplemented into the synthetic groundwater and fed to the soil column, and the column effluent will be collected and analyzed. It is anticipated that breakthrough of contaminant will be greatly retarded by the addition of apatite. If no contaminant breakthrough is observed for the amended soil within the testing period, the distribution of contaminant within the exposed column will be determined by analysis of discrete longitudinal sections removed from the column. This data will support

migration-modeling efforts.

This project has progressed through Phase I, which included development of sorption isotherms for Apatite based on batch testing with metals in solution. The results of the multiconcentration, multi element exposure study indicated that the contaminants exposed to Apatite passed the TCLP. The metals tested included Pb, Cd, Hg, and U. Column studies under Phase II are ongoing. The contract end-date for this project is June 30, 2003.

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Online Resources:

Office of Science and Technology, Technology Management System (TMS), Tech ID # 3163
<http://ost.em.doe.gov/tms>

The National Energy Technology Laboratory Internet address is <http://www.netl.doe.gov>

For additional information, please visit the Materials and Chemistry Laboratory, Inc. website at <http://www.mcl-inc.com>

For additional information on the PIMS process, please visit the PIMS-NW website at <http://www.pimsnw.com>

